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

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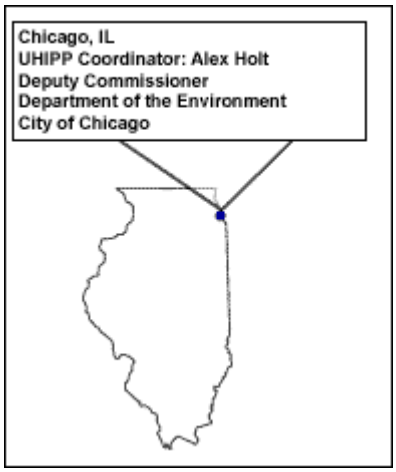


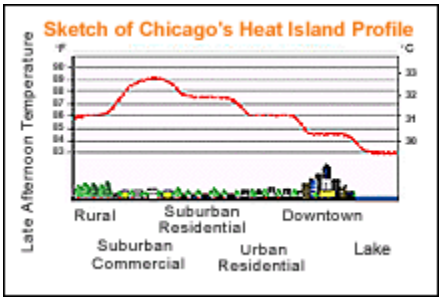
The City of Chicago is located on Lake Michigan in northeast Illinois. The city has a population of approximately three million people and covers over 225 square miles. The Chicago metropolitan region includes more than 7 million people in a six-county area and covers approximately 3,750 square miles.

Chicago's Heat Island

In 1999, researchers from Northwestern University used data from the National Climatic Data Center (NCDC) to identify the location of Chicago's heat island. They collected data from locations in Chicago that corresponded to ground-level ozone monitoring so that the relationship between ozone and temperature could be evaluated.

The researchers found that the Chicago heat island consistently appears in the western suburbs, not in the core downtown area. Lake Michigan, to a great extent, influences Chicago's climate. Further, the western suburbs are developing rapidly. The temperature gradient between areas in the far west suburbs and downtown Chicago is on average 3-5°F (1.7-2.8°C).

Before determining how heat island reduction strategies impact an area, researchers need to evaluate existing surface characteristics of the area. 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.



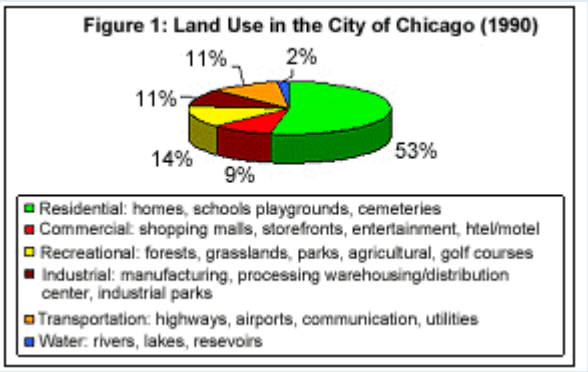
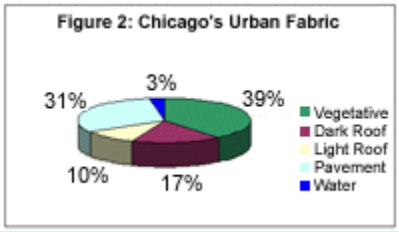


Figure 1 shows the classification and relative proportions of land use in Chicago.

Figure 2 is based on NIPC 1990 land classification data and the 1998 aerial photos, and provides an overall average urban fabric breakdown for Chicago.



Source: 1990 Land Use in Northeastern Illinois Counties, Minor Civil Divisions and Chicago Community Areas; Northeastern Illinois Planning Commission (NIPC); Data Bulletin 95-1. June 1995.

Source: Figure 43, The Urban Heat Island, Photochemical Smog, and Chicago: Local Features of the Problem and Solution, Dr. Kimberly Gray, January 2000.

Chicago's Climate

Chicago's climate is predominantly continental, ranging from warm in the summer to cold in the winter. Its climate is partially modified by Lake Michigan, and to a lesser extent by other Great Lakes.

The flat terrain of the Midwest and Lake Michigan make Chicago's weather unpredictable and frequently extreme. Summer is very warm and often humid. The highest temperatures occur throughout July and August and can reach 95-100°F (35-38°C). The coldest days are usually in January when the temperature can drop below 0°F (-18°C). Average monthly temperatures for Chicago range from 21°F (-6°C) in January to 73°F (23°C) in July.

Chicago receives an average annual rainfall of 31.7 inches per year and has an average relative humidity of 80% in the morning and 62% in the afternoon. Based on 1961-1990 NCDC data, Chicago has, on average, 752 cooling degree days and 6,536 heating degree days.

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 can also 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.

Chicago's Urban Fabric

To conduct an urban fabric analysis, where researchers determine the proportions of vegetative, roofed, and paved surface cover relative to the total urban surface in the city, Northwestern researchers used digital aerial photos taken in 1998 from 14 sample square mile sectors. These photos represented a variety of neighborhoods (e.g., industrial, commercial urban, commercial suburban, etc.). Additional photos within each square mile sample were taken to further classify mixed land use areas.

The largest portion of Chicago's urban fabric is vegetative land cover (ground and canopy cover) at almost 40%, followed by paved surfaces (31%), and total roofed area (27%). Note that not all light colored roofs are cool roofs (i.e., reflective and emissive).

The following table is based on the aerial photos and provides more detailed information on the urban fabric by land use category.

Urban Fabric Analysis for the Chicago Area

Category	Vegetative Average	Roofed Average	Paved Average
Residential - Urban (Medium/High	45%	34%	20%

Residential - Near Suburban (Medium/Low Density)	50%	27%	23%
Residential - Far Suburban (Low Density)	71%	13%	17%
Recreational	67%	7%	22%
Transportation	32%	0%	68%
Commercial Urban	16%	33%	51%
Commercial Suburban	12%	26%	62%
Industrial	10%	42%	48%

Source: Table 9, *The Urban Heat Island, Photochemical Smog, and Chicago: Local Features of the Problem and Solution* (PDF, 146 pp., 3.8 MB) Dr.

Vegetation

From 1991 to 1998, Chicago planted over 500,000 trees. As of 1998, Chicago had 4.1 million trees. Chicago's Bureau of Forestry plants a minimum of 5,000 new trees per year. Street trees are a significant part of the landscape, accounting for 10% of the city's trees and 24% of the total leaf surface area. Further, Chicago has over 120 miles of median planters and plans to install over 280 miles from 2001 to 2005.

Roofs

The amount of roofed surfaces in Chicago's far suburban and recreational areas is less than in residential-urban and industrial areas. This indicates that building density is lower in distant suburbs and recreational areas.

Pavement

Chicago's roads mostly are constructed using a nine-inch concrete base with a three-inch asphalt overlay. State and county roads are built to different specifications. Transportation, commercial suburban, commercial urban, and industrial areas have the highest percentages of paved surfaces-69%, 61%, 51%, and 48%, respectively.

The Department of Energy's Lawrence Berkeley National Laboratory currently is conducting additional urban fabric analysis work that will provide more detail on Chicago's surface composition.

Chicago's Energy Savings Analysis

Chicago has a mid-June through early-September cooling season. Air conditioning saturation in the Chicago Consolidated Metropolitan Statistical Area (CMSA) is fairly high, particularly in new residences (constructed in or after 1980) and commercial buildings. Using 1990 American Housing Survey data and 1994 Commercial Building Energy Consumption Survey information, the Department of Energy's Lawrence Berkeley National Laboratory (LBNL) calculated the total air conditioned roof area in the Chicago CSMA to be 765 million (M)ft² residential and 368 Mft² commercial (offices, retail stores, schools, hospitals and nursing homes, and grocery stores).

Modeling Methodology

LBNL analyzed the potential savings of increasing the solar reflectance of roofs on cooling energy use in the Chicago CMSA. Heat gain through a roof is a dominant component of the total cooling load of a single-story building. These loads are maximized in homes with little or no insulation.

Typically, rooftops in the United States are dark colored and have little insulation. Thus, increasing the solar reflectance of roofs provides great potential for cooling energy savings.

However, in cooler climates such as Chicago, a heating penalty often is associated with a reflective roof because less sunlight is absorbed by the roof during the heating season. In many locations and buildings, though, the savings in cooling electricity dollars is greater than the penalty in heating gas dollars. Cloudiness, snow, rain, and less incoming solar radiation, for example, minimize the potential negative impacts on heating energy.

LBNL used DOE-2 building energy software – an advanced computer program that simulates hourly building energy use – to model the impacts of increasing the 0.25 base case albedo – or solar reflectance – of residential and commercial roofs by 0.3 for residences and 0.45 for commercial buildings.

Modeling Results

LBNL calculated the following annual results for the total Chicago CSMA:

- Cooling electricity savings of 183 gigawatt-hours;
- Heating energy penalty of 1,523 giga British thermal units; and

- Net dollar savings of $10 million in 1993 dollars.

Per 1,000 square feet, LBNL calculated the following annual results:

- Cooling electricity savings of 162 kilowatt-hours;
- Heating energy penalty of 13 therms; and
- Net dollar savings of $10.

Chicago's Air Quality

Chicago has been classified as a severe nonattainment area for ozone. Illinois must reduce the region's emissions of ozone-forming chemicals by 3% per year through 2007, or until the one-hour standard is achieved and maintainable over a ten-year period.

Northwestern researchers examined 1992-1996 ozone data and found that the majority of ozone noncompliance days do not occur in downtown Chicago, but appear instead in the northern suburbs. Further, data illustrate that most ozone noncompliance days are not solely the result of temperature effects, but that atmospheric and surface transport mechanisms greatly influence the ozone distribution in Chicago.

While the Chicago data showed no positive linear relationship between temperature and ozone, temperature thresholds do seem to exist. For example, no ozone exceedances occurred at temperatures below 77°F (25°C), and 90% of the exceedances occurred at temperatures above 80°F (27°C). Further, temperatures of 95°F (35°C) show a greater proportion of exceedances relative to the total number of days in the same high range.

Chicago's active effort to reduce heat island impacts and improve air quality may have contributed to a November 1, 2001, announcement by the Illinois Environmental Protection Agency. According to that announcement, air monitoring data revealed that the Chicago metropolitan area achieved the one-hour health standard for ground-level ozone six years ahead of the federal deadline.

Chicago's Heat Island Reduction Activities

Chicago has been a leading city in launching heat island reduction measures. Some highlights of the city's activities include the following:

- Landscape Ordinance
- Energy Code
- Rooftop Garden
  - City Hall Energy Savings
  - Other Benefits

- Open Space Impact Fee Ordinance
- Asphalt Alley Reconstruction
- Parking Lot Resurfacing
- Greening

Landscape Ordinance

Established in 1991 and updated in 1999, this ordinance covers three categories of landscaping: planting trees or shrubs on parkways; landscaping to screen the perimeters of parking lots, loading docks, and other vehicular use areas; and landscaping within these same parking lots, loading docks, and other vehicular use areas.

Parkway plantings are required in the construction of any principal building; any addition or enlargement to an existing building if the new construction exceeds 1,500 ft²; any repair or rehabilitation work of an existing principal building, including interior remodeling, if the expense of this work exceeds 50% of the structure's replacement cost; construction of any parking area containing five or more spaces; and repair or expansion of existing parking areas if the number of spaces is being increased by more than 25%.

Residences of three living units or less are exempt. Parking lots, loading docks, or other vehicular use areas smaller than 1,200 ft² are exempt from screening landscaping.

The Department of Zoning co-administers the Landscape Ordinance with the Department of Streets and Sanitation's Bureau of Forestry. As of summer, 2001, more than 2,000 new trees and 8,000 new shrubs had been planted due to this ordinance. Plans were approved for an additional 6,000 new trees and over 33,000 new shrubs.

Planting standards are maintained by the Bureau of Forestry, which also must inspect and approve all parkway plant materials prior to installation. All building and zoning permit applications are reviewed by the Chicago Department of Zoning to ensure compliance with the Landscape Ordinance.

For additional information, contact the Bureau of Forestry at (312) 747-2021. Copies of the original Landscape Ordinance are available to the public by calling (312) 744-9044 or online at Chicago's Department of Environment.

Energy Code

In January 2003, Chicago amended its energy code requirements for reflective roofs. This code applies to all buildings except: separated buildings that have a peak design rate of

energy use less than 3.4 British thermal units an hour per ft² or 1.0 watts per ft² of floor area for all purposes; and unconditioned buildings (i.e., those that are neither heated nor cooled).

The amended code states that roofing materials used in roofs with slopes of 2:12 inches or less must meet the following requirements: for roofs installed on or before December 31, 2008, a minimum solar reflectance (both initial and weathered) of 0.25, when tested in accordance with American Society for Testing and Materials (ASTM) standards E 903 and E 1918, or by testing with a portable reflectometer at near ambient conditions; and for roofs installed after December 31, 2008, at least the minimum criteria to qualify for an ENERGY STAR ® label as designated by the ENERGY STAR ® program.

Rooftop Garden

Aerial view of Chicago's rooftop garden (courtesy of the City of Chicago).

Chicago began constructing its City Hall rooftop garden in April 2000 after 1.5 years of planning. In total, 20,000 herbaceous plants consisting of 156 varieties, 112 shrubs, and 37 vines were planted in a special blend of compost, mulch, and lightweight absorbent materials occupying 20,000 ft² of the 38,800 ft² roof. Rainwater is collected from 2,500 ft² of penthouse space and stored in holding tanks for periods without rain.

The adjoining Cook County building, which has a traditional black tar roof, provides good control data. Weather stations have been set up on both halves to monitor temperature, rainfall, and wind speed and direction. City Hall's initial total roof solar reflectance– or albedo– was approximately 0.27. The solar reflectance of the total roof with the gardens and walkways is 0.45.

City Hall Energy Savings

Chicago expects the City Hall green roof to generate direct energy savings through a combination of shading, evapotranspiration – or evaporation of water from leaves – and insulation, which the rooftop garden provides as part of the green roof system. Rainfall in Chicago is the heaviest during the summer months, maximizing evapotranspiration effects.

Close up view of Chicago's rooftop garden (courtesy of the City of Chicago).

Researchers used an energy model developed by the American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. to project cooling savings. The model

indicated that evapotranspiration alone (not including the effects of changes in surface color, insulation, and shade levels) eliminates the roof cooling load. That is, the heat required to transpire the water from the garden is overwhelmingly greater than the roof cooling load. The fact that over 88% of the transpiration (413,808 gallons of water from an annual total of 470,754) occurs during Chicago's six-month cooling season greatly contributes to this effect. Further, part of the green roof system included adding a new layer of insulation, thus eliminating the typical heating season heating penalty.

Projected total direct electricity savings were 9,272 kilowatt-hours per year, and the corresponding savings in natural gas for heating were 7.372 therms per year. (This calculation compares the base case R-value, or thermal resistance value, of 5.9 with the treated roof – garden and insulation – R-value 21.2.)

Other Benefits

The total available cooling effect from evapotranspiration by the City Hall rooftop garden is 730% of what is needed to eliminate the cooling load of the City Hall roof. The surplus cooling effect available for the surrounding microclimate can reduce cooling costs in buildings downwind of City Hall. Further, if green roofs were installed on all Chicago roofs – approximately 30% of the city's land is covered by building roofs – the avoided peak energy demand would be 720 megawatts.

Reduced load on the storm sewer system would be 70%.

Air quality would improve due to removal of particulates, nitrogen dioxide, ozone from or by the vegetation, and reduced power plant emissions due to reduced energy consumption. Green roofs would also increase the amount of wildlife habitat for birds and butterflies.

Open Space Impact Fee Ordinance

The purpose and legislative intent of this ordinance is to require developers of new residential properties either to pay a fee or contribute a proportionate share of open space and recreational facilities, which directly and materially benefit the developments.

Open space impact fees are earmarked for open space acquisition and capital improvements, which provide a direct and material benefit to the new development from which the fees are collected. Fees may not be used to cure existing park deficiencies. Open space impact fees must be expended within the same or a contiguous community area from which they were collected after a legislative finding by the city council that the expenditure of fees will directly and materially benefit the developments from which the fees were collected. This ordinance was last updated in 1998.

Asphalt Alley Reconstruction

Making way for a porous pavement alley (courtesy of the City of Chicago).

Before reconstruction, this 10,080 ft² alley consisted of a three-inch asphalt overlay, ten inches of concrete, and no existing sewers. A gravel pave system was chosen for the reconstruction for its urban heat island benefits. The alley presented some construction challenges including an eight-foot elevation drop and 42 residential garage accesses. The new construction made the incline more gradual and created a footing on either side of the alley that matched or replaced the entry aprons of each garage.

The new gravel pave system was installed between the footings. This gravel pave system is light in color and reflects the summer sun. It also allows rainwater to filter into the subsurface, which is mainly sand, thus reducing the storm water load on the sewer system significantly.

Raking gravel into a Gravelpave2 system (courtesy of the City of Chicago).

Parking Lot Resurfacing

At the Institute for Cultural Affairs, a 2,300 ft² parking lot was converted from asphalt to a permeable brick paver surface with a solar reflectance of approximately 0.4. While this parking lot does have a sewer system, the permeability of the brick pavers helps to reduce the amount of storm water entering that system. The parking lot was also brought into compliance with the landscape ordinance, and the Institute has plans to exceed the ordinance requirements by adding trees and perennials around the parking lot perimeter.

Greening

Chicago also is a part of a series of greening projects involving replacing concrete and asphalt with green space and reflective surfaces throughout the city.

In addition to the above activities, Chicago has launched a series of neighborhood projects intended to demonstrate the applicability of urban heat island reduction techniques at the community level.

See the City of Chicago Department of the Environment for more information on Chicago's heat island reduction activities.