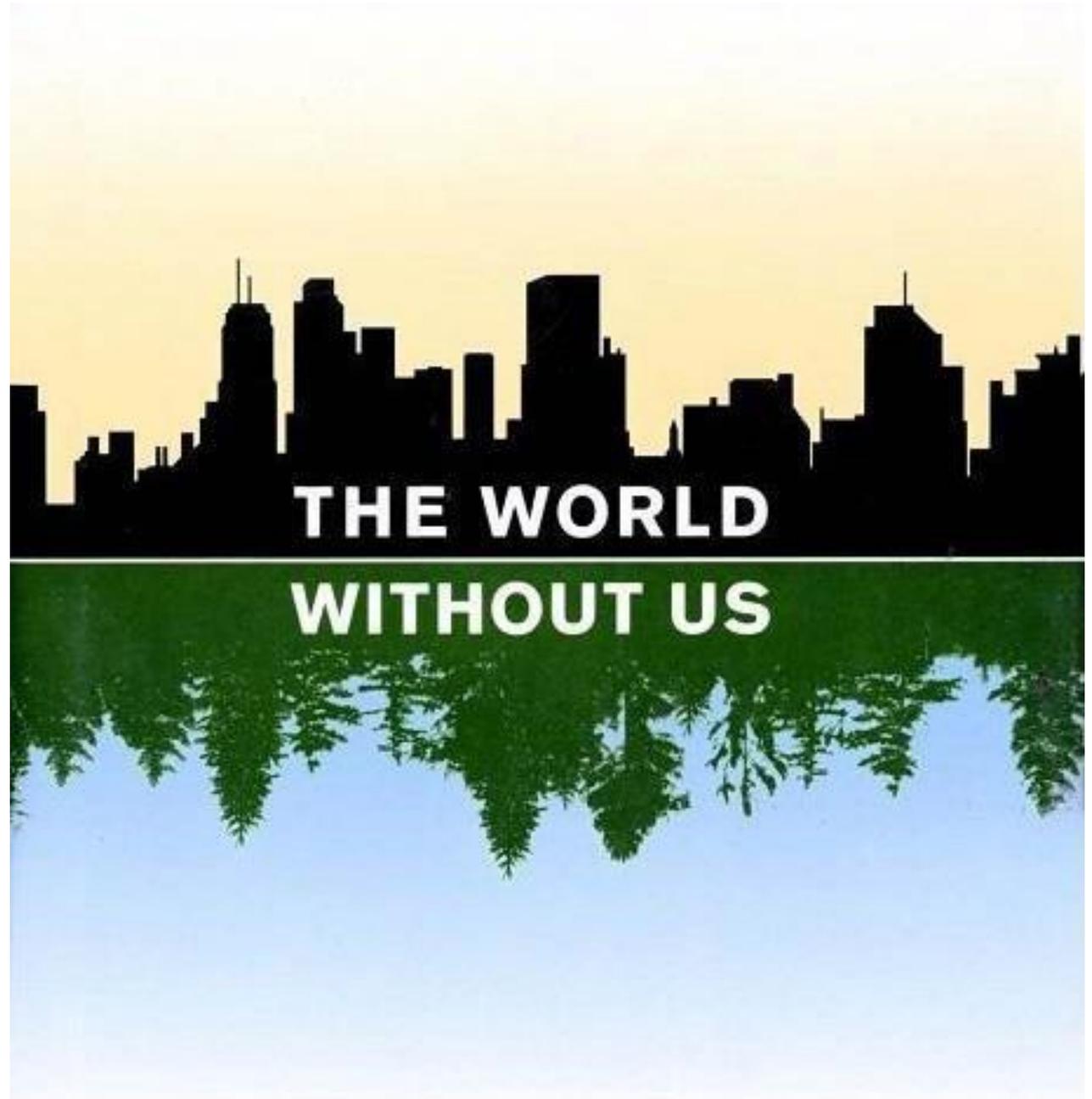




# Urban Heat Island and Climate Change

By:

Sowgol Shooshtarian



## Introduction:

One of the basic elements that can divide an urban to two main parts such main city part and rural (surroundings) is the climate that prevails over urban environments. Hard and paved surfaces on buildings and streets that have gradually replaced preexisting natural landscapes make a distinct between these two areas. Subsequently, solar energy is absorbed into roads and rooftops, and this event causes an increase in the surface temperature of urban structures and makes it 50 - 70 °F higher than the ambient air temperatures. Also, some of this solar energy reflects in air atmosphere and trapped there.

The image below indicates albedo values for various urban surfaces; the albedo is a measure of the amount of solar energy reflected by the surface. Therefore, low albedo implies higher surface temperatures since the larger amounts of energy are absorbed. As surfaces throughout an entire community or city become hotter, general ambient air temperature increases. This phenomenon, known as an **urban heat island** and it can raise air temperature in a city by 2 - 8 °F. (Figure 1)

This higher temperature by the urban heat island in metropolitans such as New York , San Francisco, Washington DC, Tokyo can have many adverse effects on public health, climate change, economy of

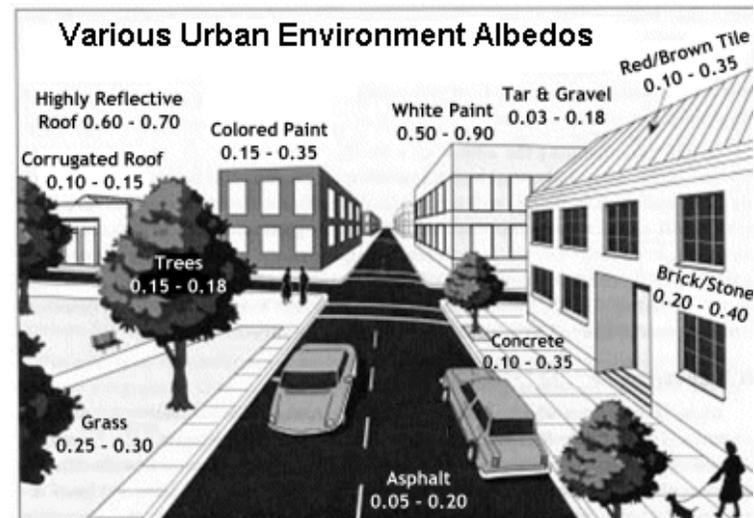


Fig 1 - Various Urban Environment Albedos. (USEPA, 2012)

society and totally health of global people. ([http://www.ghcc.msfc.nasa.gov/urban/urban\\_heat\\_island.html](http://www.ghcc.msfc.nasa.gov/urban/urban_heat_island.html), Last updated 1999) This important has been the subject of numerous studies in recent decades and is exhibited by many major cities around the world. These include Athens, Paris, Singapore and Kuala Lumpur, Tokyo and Washington, DC. Regional studies have also been carried out in Australia and Argentina, China, South Korea and the United States. (Streutker,2001) For example, this phenomenon can increase the demand for cooling energy in commercial and residential buildings. Consequently, this increased demand for energy can cost consumers and municipalities thousands of additional dollars in air conditioning bills in order to maintain comfort levels. In addition, increased electricity generation by power plants leads to higher emissions of sulfur dioxide, carbon monoxide, nitrous oxides, and suspended particulates, carbon dioxide and greenhouse gases which are known to contribute to global warming and climate change. Moreover, summer heat islands often pick up the pace of the formation of harmful smog, as ozone precursors such as nitrous oxides (NO<sub>x</sub>) and volatile organic compounds (VOCs) combine photochemically to produce ground level ozone. ([http://www.ghcc.msfc.nasa.gov/urban/urban\\_heat\\_island.html](http://www.ghcc.msfc.nasa.gov/urban/urban_heat_island.html), Last updated 1999)

This paper will provide an overview of different types of urban heat islands, methods for identifying them, and factors that contribute to their development and totally features of that in case study city which is New York city.

## What is an Urban Heat Island?

Many urban and suburban areas experience elevated temperatures compared to their outlying rural surroundings; this difference in temperature is what constitutes an urban heat island. The annual mean air temperature of a city with one million or more people can be 1.8 to 5.4°F warmer than its surroundings, (Oke, 1997) and also Oke has clarified ,in “Boundary Layer Climate” 1987, that on a clear, calm night, this temperature difference can be as much as 22°F. Even smaller cities and towns will produce heat islands, though the effect often decreases as city size decreases.

Urban Heat Islands, which are discussed in this paper, are separated into two groups; surface and atmospheric urban heat islands. These two heat island types differ in the ways they are formed, the techniques used to identify and measure them, their impacts, and to some degree, the methods available to mitigate them. (USEPA, 2012)

### I. Surface Urban Heat Islands

On a hot, sunny summer day, the sun can heat dry, exposed urban surfaces (such as roofs and pavement) to temperatures 50 to 90°F hotter than the air, while shaded or moist surfaces ,which are often in more rural surroundings, remain close to air temperatures. Surface urban heat islands are typically present day and night, however are likely to be strongest during the day when the sun is

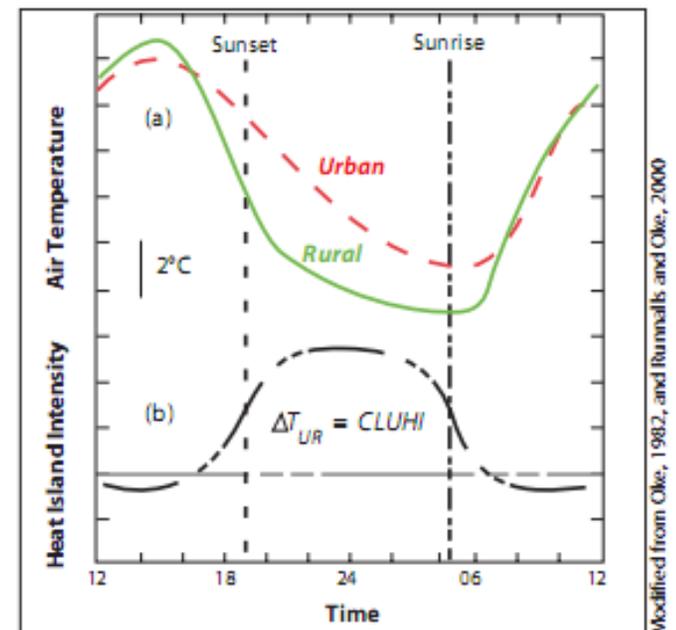
shining. The difference in daytime surface temperatures between developed and rural areas, on average, is between 18 to 27°F; however, the difference in nighttime surface temperatures is typically smaller, at 9 to 18°F. The magnitude of surface urban heat islands varies with seasons, due to changes in the sun's intensity as well as ground cover and weather. As a result of such variation, surface urban heat islands are typically largest in the summer. (USEPA, 2012)

## II. Atmospheric Urban Heat Islands

Warmer air in urban areas compared to cooler air in nearby rural surroundings defines atmospheric urban heat islands. Experts often divide these heat islands into two different types:

**Canopy layer urban heat islands:** exist in the layer of air where people live, from the ground to below the tops of trees and roofs.

And **boundary layer urban heat islands:** start from the rooftop and treetop level and extend up to the point where urban landscapes no longer influence the atmosphere. This region typically extends no more than one mile from the surface. Canopy layer urban heat islands are the most commonly observed of the two types.



**Fig 2 -** Diurnal Evolution of the Urban Heat Island during Calm and Clear Conditions (USEPA, 2012)

Atmospheric heat islands vary much less in intensity than surface heat islands. As it was mentioned before, on an annual mean basis, air temperatures in large cities might be 1.8 to 5.4°F warmer than those of their rural surroundings. Researchers typically measure air temperatures through a dense network of sampling points from fixed stations or mobile traverses, which are both direct measurement methods.(Figure 2) (USEPA, 2012)

### How Urban Heat Islands form

While many factors contribute to urban heat island formation, only four main reasons are discussed here in brief which they are: Reduced vegetation in urban, properties of urban materials, urban geometry and anthropogenic heat emissions.

**Reduced vegetation in urban:** In general, trees and vegetation provide shade, which helps decrease surface temperatures. They also help reduce air temperatures through a process called evapotranspiration, in which plants release water to the surrounding air, dissipating ambient heat. However, urban areas have reduced trees and vegetations by dry, impervious surfaces, such as conventional roofs, sidewalks, roads, and parking lots. Also as it is mentioned before, Urban Heat Islands and increased temperature of the urban is significantly due to size of that and as they develop, more vegetation is lost, and more surfaces are paved or covered with buildings. Therefore, the change in ground cover results in less shade and moisture to keep urban areas cool. Built up areas evaporate less water which contributes to elevated surface and air temperatures.

**Properties of urban materials:** In particular, they are solar reflectance, thermal emissivity, and heat capacity, also influence urban heat island development, as they determine how the sun's energy is reflected, emitted, and absorbed. 52 percent of solar energy is infrared, which is felt as heat. Energy in all of these wavelengths contributes to urban heat island formation. Solar reflectance, or albedo, is the percentage of solar energy reflected by a surface. Also, it is correlated with a material's color. Darker surfaces tend to have lower solar reflectance values than lighter surfaces. Urban areas typically have surface materials, such as roofing and paving, which have a lower albedo than those in rural settings. Consequently, built up communities generally reflect less and absorb more of the sun's energy. This absorbed heat increases surface temperatures and contributes to the formation of surface and atmospheric urban heat islands. Another important property is a material's heat capacity, which refers to its ability to store heat. Many building materials, such as steel and stone, have higher heat capacities than rural materials, such as dry soil and sand. As a result, cities are typically more effective at storing the sun's energy as heat within their infrastructure. Downtown metropolitan areas (such as Manhattan in New York City) can absorb and store twice the amount of heat compared to their rural surroundings during the daytime.

**Urban geometry:** The height and spacing of buildings affects the amount of radiation received and emitted by urban infrastructure. In developed areas, surfaces and structures are often at least partially obstructed by objects, such as neighboring buildings, and become large thermal masses that cannot release their heat very readily because of these obstructions. Especially at night, the air above urban centers is typically warmer than air over rural areas. Nighttime atmospheric heat islands can have serious health implications for urban residents during heat waves. Researchers often focus on an aspect of urban geometry called urban

canyons, which can be illustrated by a relatively narrow street lined by tall buildings. In case study city, which it is very known for its tall buildings and narrow roads around them,

**Anthropogenic heat emissions:** it contributes to atmospheric heat islands and refers to heat produced by human activities. It is estimated by totaling all the energy used for heating and cooling, running appliances, transportation, and industrial processes. Anthropogenic heat varies by urban activity and infrastructure, with more energy-intensive buildings and transportation producing more heat. For example transportation or industrial processes in New York City, with approximately 20 million populations, can be a considerable concern.

Moreover, weather and geographical location are additional factors. For example, in certain conditions, such as clear skies and calm winds, can press forward urban heat island formation, or closeness to large water bodies and mountainous terrain can influence local wind patterns, and they can change the formation of urban heat island. (USEPA, 2012)

## **Why Do We Care about Urban Heat Islands**

Impact of urban heat islands can affect a community's environment and quality of people's life. While some heat island impacts seem positive, such as lengthening the plant-growing season, most of them are negative such as increased energy consumption, elevated emissions of air pollutants and greenhouse gases, compromised human health and comfort and impaired water quality.

**Energy Consumption:** as it is mentioned before, with increase of temperature, there will be an increase in electricity consumption. This peak urban electric demand increases 1.5 to 2 percent for every 1°F increase in summertime temperature. Steadily increasing downtown temperatures over the last several decades mean that 5 to 10 percent of community-wide demand for electricity is used to compensate for the heat island effect.

**Air Quality and Greenhouse Gases:** higher temperatures can increase energy demand and also higher levels of air pollution and greenhouse gas emissions. Currently, most electricity in the United States is produced from combusting fossil fuel. Therefore, pollutants from most power plants include sulfur dioxide, NO<sub>x</sub>, particulate matter, CO, and mercury. These pollutants are harmful to human health and contribute to complex air quality problems such as acid rain. Further, fossil-fuel-powered plants emit greenhouse gases, particularly carbon dioxide which leads to global climate change. Moreover, as it was said before NO<sub>x</sub> and VOCs emitted from fossil fuels can increase the rate of ground-level ozone formation

**Human Health and Comfort:** increased surface temperatures, reduced cooling, and higher air pollution levels can affect human health by contributing to general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and heat-related mortality. Urban heat islands can also exacerbate the impact of heat waves.

Susceptible populations, such as children, older adults, and those with existing health conditions, are at particular risk from these events. For example, in 1995, a mid-July heat wave in the Midwest caused more than 1,000 deaths. While it is rare for a heat wave to

be so destructive, heat-related mortality is not uncommon. The Centers for Disease Control estimates that from 1979 to 1999, excessive heat exposure contributed to more than 8,000 premature deaths in the United States. This figure exceeds the number of mortalities resulting from hurricanes, lightning, tornadoes, floods, and earthquakes combined.

**Water Quality:** degraded water quality mainly happens by thermal pollution. Field measurements from one study showed that runoff from urban areas was about 20-30°F hotter than runoff from a nearby rural area on summer days when pavement temperatures at midday were 20-35°F above air temperature.

A study in Arlington, Virginia, recorded temperature increases in surface waters as high as 8°F in 40 minutes after heavy summer rains. Also, water temperature affects all aspects of aquatic life, especially the metabolism and reproduction of many aquatic species. Subsequently, rapid temperature changes in aquatic ecosystems resulting from warm stormwater runoff can be particularly stressful. Brook trout, for example, experience thermal stress and shock when the water temperature changes more than 2 to \ in 24 hours. (USEPA, 2012)

## **Strategies to reduce Urban Heat Islands**

Some major strategies that can be done for reducing urban heat island effect are only named below briefly and then some strategies that have been done in New York City will be discussed as well.

- ❖ increasing tree and vegetative cover
- ❖ creating green roofs (also called "rooftop gardens" or "eco-roofs");
- ❖ installing cool—mainly reflective—roofs;
- ❖ and using cool pavements. (USEPA, 2012)

### **Mitigation strategies in New York City**

Three main active mitigation strategies are:

- **Cool roof in New York City:** In 2008 New York City made a building code or law that requires most new buildings to have 75% of the roof area covered with a reflective, white coating, or to be Energy Star® rated as highly reflective. To date nearly 1,600 volunteers have coated more than 1.5 million square feet of rooftops throughout the city. This building code will help save money, preserve roof structure and cooling equipment, reduce energy use, reduce carbon emissions, and combat the urban heat island effect.
- **Green roof in New York City:** Earth Pledge, a non-profit organization in New York City, runs a Green Roofs Initiative that supports the development of green, vegetated rooftops in urban areas to prevent stormwater runoff pollution, lower urban temperatures, and improve air quality.
- **Mixture of green roof and cool roof in the Bronx:** The goals include gathering research on local impacts, establishing a resource for the community, educating New Yorkers on the benefits of green roofs, and advocating sustainable building

practices. The demonstration project has become a springboard for developing a local green and cool roof installation company to provide employment opportunities in the South Bronx area. (USEPA)

## Conclusion

All in all, urban heat islands, which can increase surface temperature of cities especially in metropolitans such New York City, can also be known as one of the most important concerns for changing the global climate and in addition, they have significant effects on human health and other environmental issues. Therefore, for reducing and preventing such this phenomenon, it is better to adopt a sustainable strategy for our buildings and cities in advance.

## References:

- Oke, T.R, Urban Climates and Global Environmental Change. In: Thompson, R.D. and A. Perry (eds.) Applied Climatology: Principles & Practices. *New York, NY: Routledge.* pp. 273-287. **1997**
- Oke. T.R.. Boundary Layer Climates. *New York, Routledge,* **1987**
- Reducing Urban Heat Islands: Compendium of Strategies Urban Heat Island Basics, USEPA, Last Updated June 21 2012, <http://www.epa.gov/hiri/resources/pdf/BasicsCompendium.pdf>
- Reducing Urban Heat Islands: Compendium of Strategies Heat Island Reduction Activities, USEPA, Last Updated June 21 2012, <http://www.epa.gov/hiri/resources/pdf/ActivitiesCompendium.pdf>
- EPA's Urban Heat Island Community Actions Database <http://yosemite.epa.gov/gw/heatisland.nsf/HIRIInitiativeTypesbyState?openview&New+York>
- Streutker D. R, "A Remote Sensing Study Of The Urban Heat Island Of Houston, Texas", *Department Of Physic And Astronomy, Rice University, Houston. Texas 77005, Usint. J. Remote ~G, 2002, Vol. 23; No. 13,2595-260, 2001*
- [http://www.ghcc.msfc.nasa.gov/urban/urban\\_heat\\_island.html](http://www.ghcc.msfc.nasa.gov/urban/urban_heat_island.html)